Variation in major element oxide with time in the soils of Peshawar Basin: their comparison with the normal agricultural soil

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Abstract

The present study is aimed to monitor the major and minor element oxides of the soils of Peshawar basin. The results were compared with the standards of the element oxides fixed for normal agricultural soils. The findings of this study showed that SiO_2, TiO_2 and Fe_2O_3 were within the permissible limit in majority of the soil samples of the basin, while Al_2O_3, CaO and Na_2O exceeded the maximum permissible limit. The geogenic sources include weathering of calcareous rocks such as limestone and dolomite and water logging and salinity have contributed to the enrichment of Al, Na, Ca and Mg in certain areas of the basin.

Keywords: Major oxides; Agricultural soil; Geogenic sources.

1. Introduction

Soil pollution can affect the normal growth of plants and crops and can contaminate surface and ground waters and thus reduces the amount of land for cultivation and habitation (Srivastava, 1995). Soil is generally altered by chemical, physical and biological processes which support rooted plant life. There are certain major elements including silicon (Si), aluminum (Al), calcium, (Ca) magnesium, (Mg) iron, (Fe) sodium, (Na) potassium,(K) manganese, (Mn) phosphorus ,(P) and titanium(Ti) in soils which are mainly released from parent material mostly overlain by igneous or sedimentary rocks (Ramussen, 2007; Nael et al., 2009). These elements are also released from fertilizers, sewage sludge, chemical industries, irrigation water, pesticides, and coal combustion residues (Senesi et al., 1999; Payne et al., 1988).

Copper (Cu), zinc (Zn), iron (Fe), manganese (Mn), molybdenum (Mo) and boron (B) are essential micronutrients required for normal plant growth but become toxic when exceed the permissible levels. It is due to the fact that heavy metals in water (Weber, 1981) and metal polluted soil may result in human exposure to environmental toxicants (Baranowska, 1993; Sommers, 1977).

Peshawar is one of the major metropolis of the country and provincial capital of the Khyber Pakhtunkhwa (KP). Peshawar basin has 4.8 million population and is situated at the southern foothills of Himalayas between the longitude 71^0 $15^/$ and 72^0 $45^/$ E and latitude 33° $45^/$ and 34° $30^/$ N in KP province adjacent to the Afghanistan border (Nasreen, 2006). The basin, covering an area of about 5500 km^2, is present at the southern margin of the Himalayas. It is surrounded by Khyber mountain ranges in the northwest, Swat mountain ranges in the northeast and Attock-Cherat mountain ranges in the south. There are three important rivers flowing in the Peshawar basin (i.e., Kabul River, Swat River and Bara River). Besides these rivers there are several perennial and non-perennial streams that contribute to the drainage of Peshawar basin and most of them discharge into the Kabul River. Peshawar and Mardan are densely populated areas having approximately 2 million inhabitants in Peshawar and 0.5 million in Mardan. The majority of the population (i.e., 53 percent) is employed in agricultural sector. The cultivated area is 400000ha of which 65 percent is irrigated either with surface water or ground water (Khyber Pakhtunkhwa Development Statistics, 2010).

Like other big cities of Pakistan the environment is being polluted ruthlessly and

carelessly in the Peshawar basin too (Khyber Pakhtunkhwa Development Statistics, 2010). For over two decades the locals living in Peshawar basin, have been complaining about the pollution and its impacts on flora and fauna. The rivers of the basin and its tributaries have been blamed for a high prevalence of skin diseases in humans as well as maladies in livestock. The river Kabul along with its tributaries was investigated in detail for the presence of pollution load by IUCN (1994) and reported alarming concentration of organic pollutants, heavy metals and foecal colifom in the river.

The anthropogenic pollution is mainly due to the application of agrochemical, release of sludge and wastewater from municipalities and industries is the major cause of soil pollution (Sommers, 1977). Major and trace element geochemistry of soil can provide useful information on geochemical baseline, soil fertility and can play a vital role in agricultural activities (Marques et al., 2004). Some researches performed detail studies on the pollution-related issues of Peshawar metropolis and Peshawar basin (Hamidullah et al., 1999; Tariq, 2001). The above studies though provided a baseline with respect to the time when these studies were performed, however, environmental issues needed to be monitored regularly and, therefore, a time based study of all the components of the environment in the basin was felt to be initiated and carried out on regular intervals.

The trace element concentration in the soil samples in Peshawar basin has already been investigated and exceeds permissible limits (Nasreen, 2006). The present study is mainly based on monitoring the pollution load due to major elements in soils of the Peshawar basin with passage of time by repeating these studies at specific interval of time to take account of environmental problems in future.

2. Methodology

2.1. Sampling

2.1.1. Collection of soil samples

Peshawar basin is an intra-mountain and one of the largest basin in the Khyber Pakhtunkhwa Province of Pakistan. The major cities of basin include Peshawar, Nowshera, Charsadda and Mardan. It is mainly irrigated by the river Kabul, river Swat river and their tributaries. During the present study various promising areas of Peshawar basin in regard to contamination/hazardous risks were selected for soil sampling in January 2003 and January 2004. Representative soil samples were collected from the same locations as that of Tariq (2001). A total of about thirty-eight soil samples were collected from Peshawar basin including Mardan, Charsadda, Nowshera and Peshawar (see Fig. 1).

The samples were divided into two horizons "A" and "B". Horizon "A" represents the core sample at a depth of 0-20 cm and horizon "B" represents a core sample from a depth of 20-40 cm. The collected samples were properly labeled and transferred to polythene bags that were further placed into canvas bags. The color, texture and loose fragments of these samples were noted on site.

2.1.2. Sample preparation

The soil samples were air dried and selected portion of the samples were pulverized in a tungsten carbide ball mill to 200 mesh size i.e. 74 µm. About 50g of individual sample was collected after proper quartering and coning. During this whole process greater care was practiced to avoid contamination. The powdered samples were stored in the air tight glass bottles. These bottles, after removing the lids, were kept in the oven at 110 ºC for two hours in order to remove the moisture.

2.2. Laboratory analysis

2.2.1. Stock solutions

Two types of stock solutions were prepared by the following methods:

Stock solution A

HF and $HClO_4$ digestion method: The method of Jeffery and Hutchison (1986) was used for the preparation of stock solution A. 0.5g of powdered soil sample was accurately weighed in a Teflon beaker and was moist with few drops

of deionized water. Then 10 ml of concentrated HF (49%) and 4 ml of concentrated $HClO_4$ (70%) was added to it. The sample was heated on a hot plate at low temperature until a small portion was evaporated. The beaker was then removed from the hot plate and was cooled for few minutes. Then 2 ml of $HClO_4$ was added and was again kept on hot plate until dry paste was obtained. 4 ml of $HClO_4$ and about 20 ml of deionized water was added to it and heated again until paste was obtained. It was then dissolved in deionized water and made to the volume in 250 ml volumetric flask. Certified rock standards (G-2, AGV-1, W-2) were digested using the same procedure as that for soil sample solutions (stock solution A). These solutions were used for the determination of Fe, Al, Mn, Ca, Mg, Na, K, P and Ti.
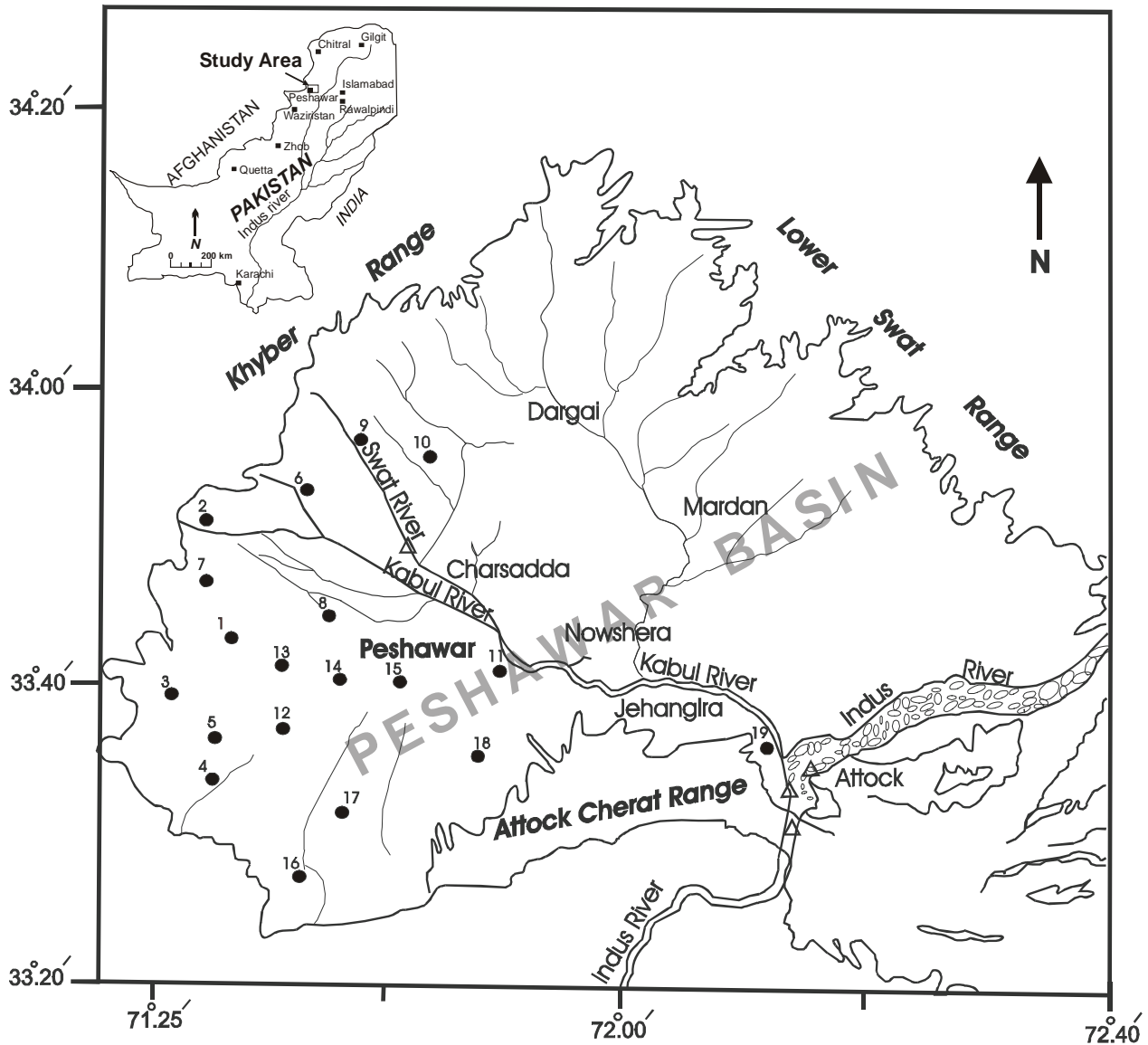

Fig. 1. Map showing location of samples in the study area.

Stock solution B

Sodium hydroxide fusion method: The method of Jeffery and Hutchison (1986) was also used to prepare the stock solution B. 30g of NaOH pellets were dissolved in 100 ml deionized water and stored in a polythene bottle. Then 5 ml aliquots of NaOH solution were added to a series of already cleaned nickel crucibles. The crucibles were kept on hot plate at about 100 ^{0}C for complete dryness. These were then cooled in a dessicator. Accurately weighed 0.05g of soil samples and certified rock standards were added to separate crucibles. One of these crucibles was used for the preparation of blank. The crucibles were covered with lids and each crucible was heated to dull redness over a bunsen burner for a period of 5 minutes. The crucibles were swirled while hot. When cooled, deionized water (5-10ml) was added to each crucible. The contents of each crucible were washed with deionized water into respective polythene beakers and gradually added 10 ml of concentrated HCl. The resulting solution of each sample was transferred to one liter volumetric flask separately and was made to the volume with deionized water and stored in polythene bottles for the determination of silica and alumina.

2.2.2. Instrumental analyses

Major element analyses of already prepared stock solutions (A and B) were carried by using SP8-400 PYE Unicam UV/VIS spectrophotometer and Perkin Elmer 3300 Atomic absorption. The SiO_2 and Al_2O_3 and TiO_2 and P_2O_5 determined in stock solution A and B respectively by using UV/VIS spectrophotometer. While Fe, Mn, Ca, Mg, Na and K were determined in stock solution A by using Atomic absorption. Great care was taken while analyzing samples on these instruments. These instruments were properly calibrated by using working standards and the accuracy of analyses was confirmed by analyzing certified reference materials (G-2, AGV-1, W-2).

3. Results

3.1. General characterization

The locations of representative soil samples of horizon A and B of the agricultural land, collected during the month of January in 2003 and 2004, are shown in Figures 2 and the data of major element oxide are given in Table 1. The soil of the Peshawar basin was classified as (1) Peshawar piedmont (2) Peshawar lacustrine (3) Peshawar flood plain by Tariq (2001) and the same classification was used here. The general characterization and comparison of chemical data of the soils among each other and with that of Tariq (2001) for the Peshawar basin are graphically presented in Figures 2 to 9.

3.2. Elemental composition

The major element oxides (i.e., SiO_2, Al_2O_3, Fe_2O_3, MgO, CaO, Na_2O and K_2O) and the minor element oxides (i.e., TiO_2, MnO and P_2O_5) in various types of soil samples of the Peshawar basin were evaluated in regard to their variation with time as well as with their possible effects on the agricultural soils. The geochemical pattern of soil pollution in the environment is a matter of great concern over the last few decades (Warren and Birch, 1987; (Soylak et al., 2000). Major element oxides such SiO_2, Al_2O_3, Fe_2O_3 and TiO_2 are the major components of soil showing resistant to weathering (Orescanin et al., 2009), while CaO is less resistant to weathering and can be easily eroded (Loughnan, 1969). The Peshawar basin which is dominated by calcareous rocks (Tariq, 2001) seems to be the major sources for some of the major elements and their concentration need regular monitoring at different time intervals. Later section will give a brief discussion of variation in concentration and their effects on agricultural activities of the Peshawar basin.

3.2.1. Major element oxides

Silica (SiO_2): Silica is essential element for soil, rock mineral structures, plants and animals in trace amount and has great effect on physical and chemical properties of soil (Kebede, 2009). It lodges in cell walls and provide physical strength and resistance to insects and fungal attacks. also add in overcoming plant injury. It also helps in reducing soil salinity and improvement of photosynthetic activity in plants (Nasseri et al., 2012). Silicon is also essential for animals in trace amounts. The SiO_2 concentration in the normal soil is 70.29 wt.% (Bohn et al., 2001).
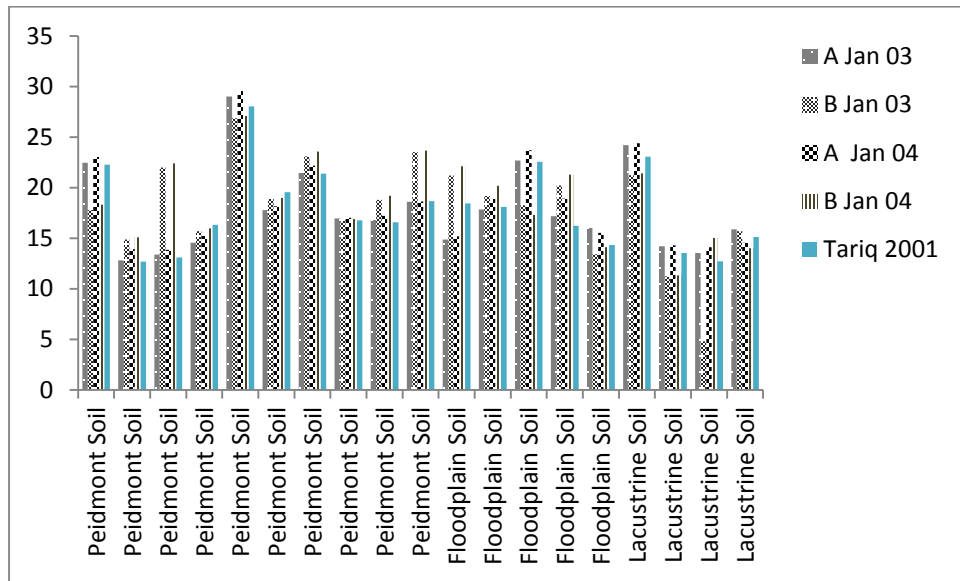
table 1

Fig. 2. Alumina concentration (wt.%) in Peshawar piedmont, floodplain and lacustrine soils during different times.
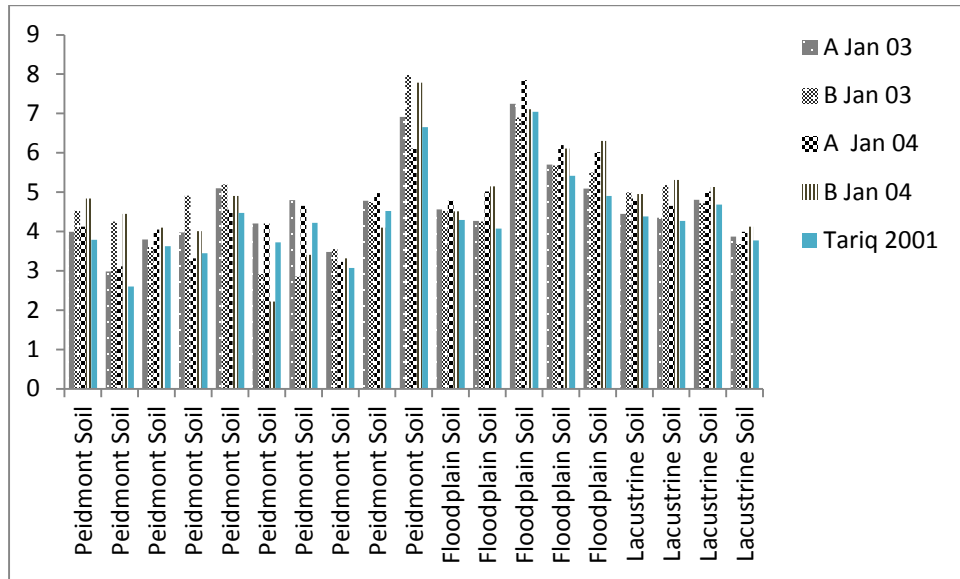

Fig. 3. Concentration of Fe2O3 (wt.%) in Peshawar piedmont, floodplain and lacustrine soils during different times.
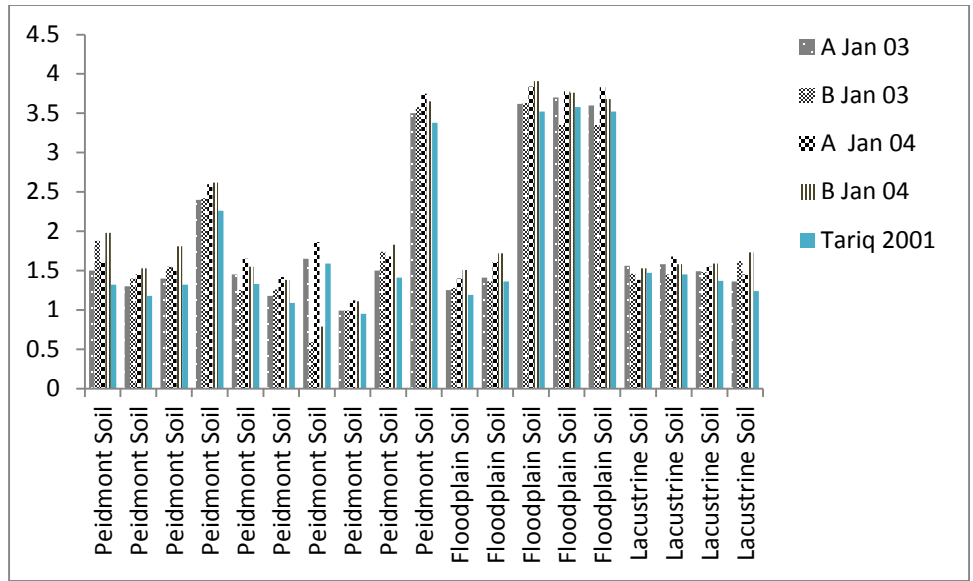
Fig. 4. Concentration of MgO (wt.%) in Peshawar piedmont, floodplain and lacustrine soils during different times.
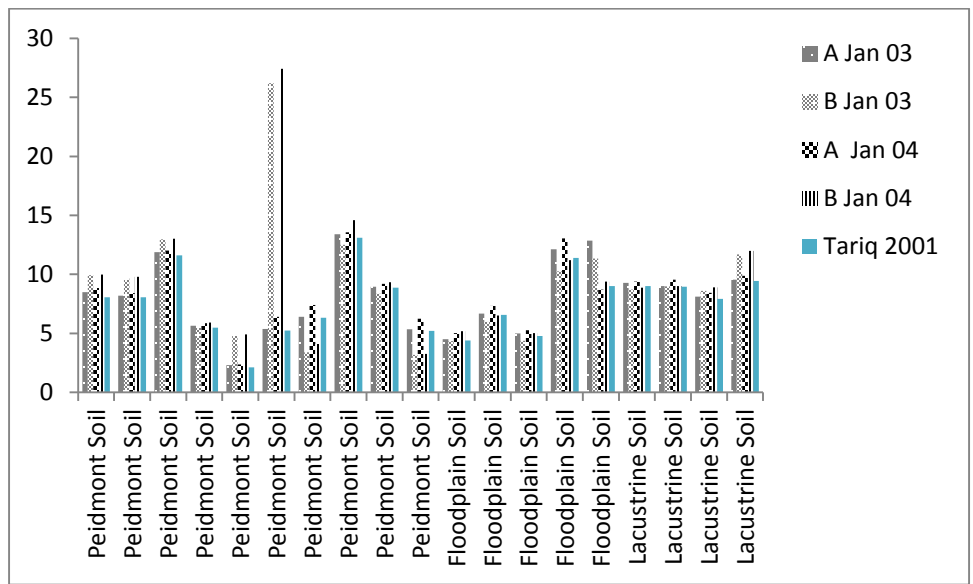

Fig. 5. Concentration of CaO (wt.%) in Peshawar piedmont and floodplain soils during different times.
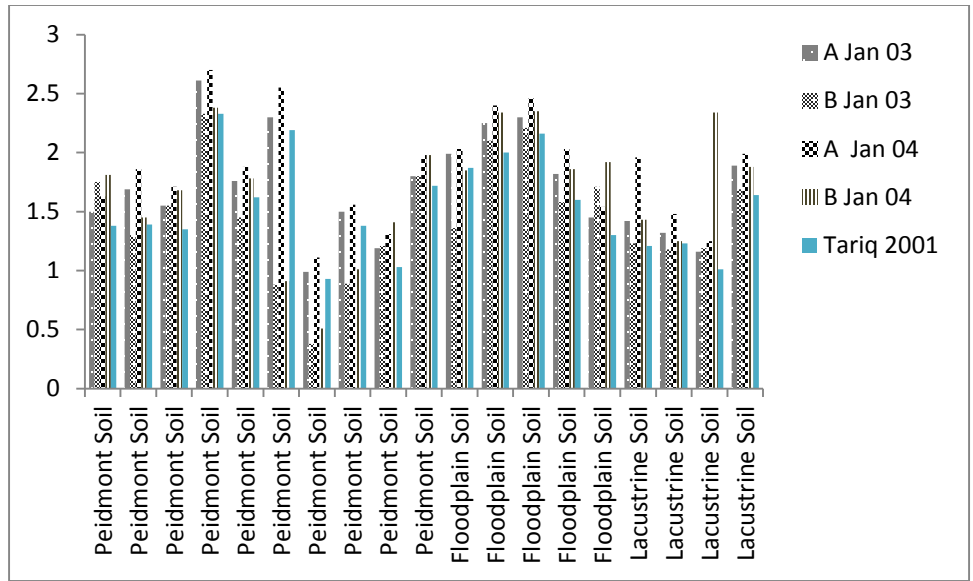
Fig. 6. Concentration of Na2O (wt.%) in Peshawar piedmont, floodplain and lacustrine soils during different times.
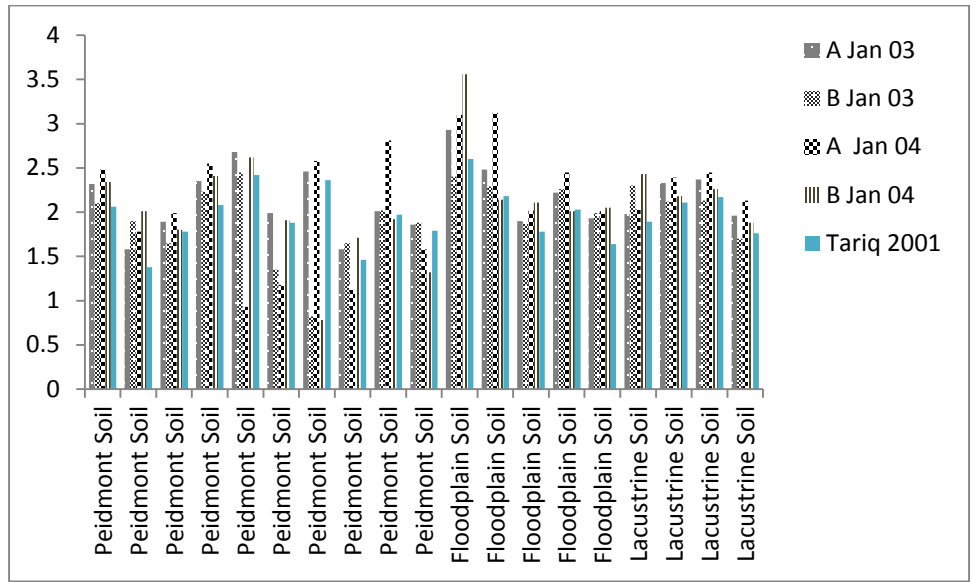

Fig. 7. Concentration of K2O (wt.%) in Peshawar piedmont, floodplain and lacustrine soils during different times.
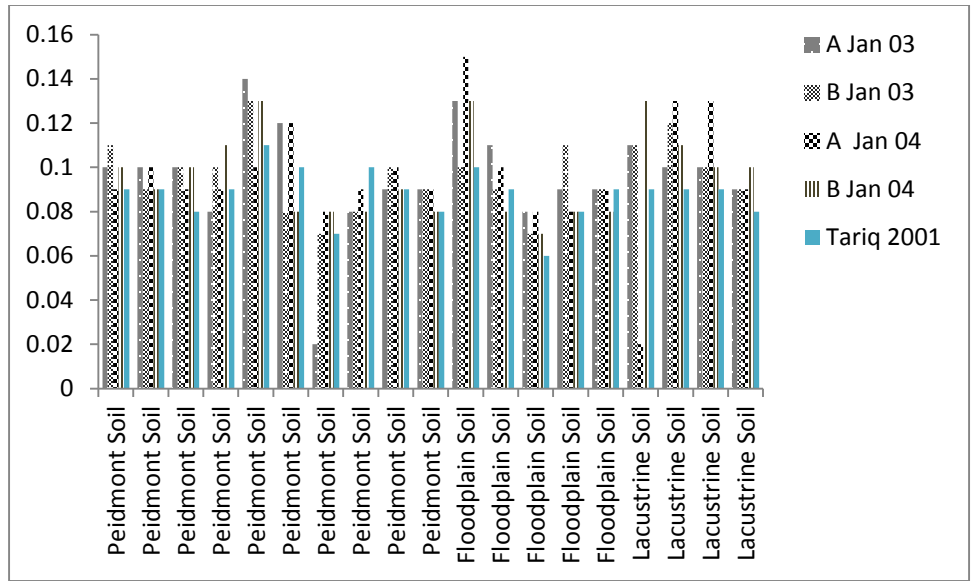
Fig. 8. Concentration of MnO (wt.%) in Peshawar piedmont, floodplain and lacustrine soils during different times.
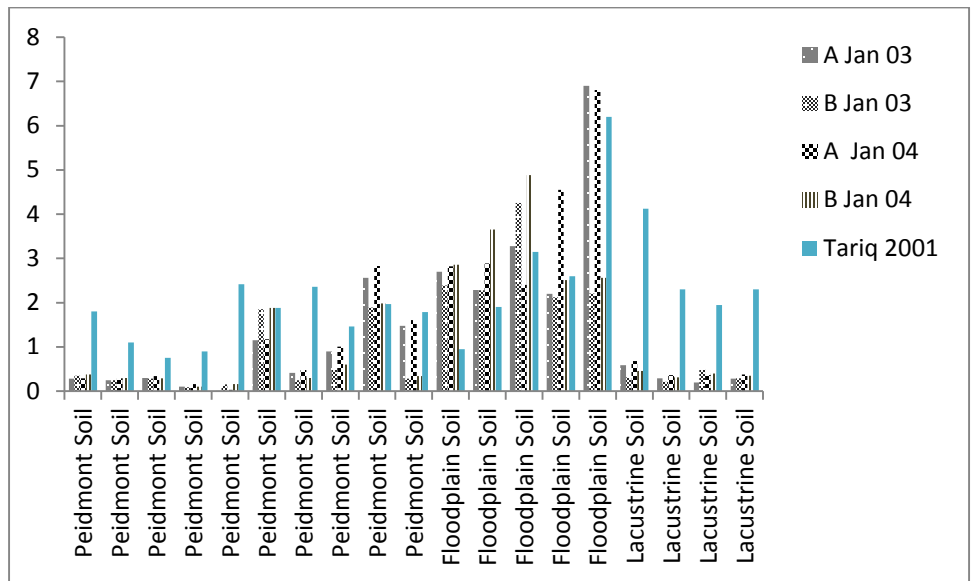

Fig. 9. Concentration of P2O5 (wt.%) in Peshawar piedmont, floodplain and lacustrine soils during different times.

No systematic increase or decrease of SiO_2 was found with change in depth from horizon A to horizon B and also there was no significant variation in the silica contents of the soils of the basin with the passage of time. The SiO_2 contents ranged from 40 to 59 wt.%, 44 to 59 wt.% and 45 to 57 wt.% in the soils of Peshawar piedmont, Peshawar floodplain and Peshawar lacustrine soils respectively (Table 1). The data suggest that SiO_2 concentration of the soils of Peshawar basin were within the range of normal soil and are, therefore, considered safe for agricultural use.

Alumina (Al_2O_3): Al_2O_3 is essential for understanding soil forming process, soil chemistry and physicochemical properties of soils (Bera et al., 2005). It is closely connected to soil acidity which is the reaction of water with exchangeable Al^{+3} on the surface of soil particles. The Al^{+3} is tightly bound to clay surface; the exchangeability of Al^{+3} depends on the concentration and action change of the salts in the extracting solution. While other major exchangeable cations are leached from soils during weathering, Al^{+3} is retained in soils as solid-phase (Al OH_3). The amount of each exchangeable and water soluble ions increase with acidity. Only Al^{+3} is a common exchangeable cation in soils and is significant only in moderately to strongly acid soils (Bohn et al., 2001; Black, 1968).

The normal soil usually has 13.22 wt.% of Al_2O_3 (Bohn et al., 2001). The Al_2O_3 content of the soil samples collected during the month of January in 2003 and 2004 from the Peshawar piedmont, Peshawar floodpain and Peshawar lacustrine soils of the Peshawar basin along with the Al_2O_3 concentration obtained by Tariq (2001) from the similar soils were graphically presented in Figure 2 and was evident that the Al_2O_3 content varied with the depth in most of the soils but there was no significant change in the concentration of Al_2O_3 with the passage of time. The Al_2O_3 contents varied from 12 to 24 wt.% in the Peshawar piedmont soils, from 13 to 24 wt.% in the Peshawar flood plain soil and from 11 to 24 wt.% in the Peshawar lacustrine soil of the Peshawar basin (Table 1). Majority of the soils samples of the Peshawar basin had Al_2O_3 contents higher than the normal soil and, therefore, need precautionary measure for agricultural use.

Iron (Fe_2O_3): Iron is common constituent in many primary and secondary minerals and is generally not deficient in many soils. It is also the major constituent of soils with iron content between 0.5 to 5 wt.% depending on the parent material of the soil type. The presence of iron in the soils is very essential because it is an important component of chlorophyll-protein complexes in plants and terminal respiration. It is also required for nitrate and sulfate reduction and assimilation. If iron is unavailable to the plants from the soil, the chlorophyll-protein complex is incomplete, causing a yellowing (chlorosis) of the plant tissues instead of the healthy normal green color. If iron is present in high concentration (>10 wt. %) in the soil, its availability to plants is high and hence cause toxicity in the growing plants. Its toxicity includes the increase in polyphenol oxidase activity, causing leaf bronzing and reducing the root oxidation power (Dobermann and Fairhust, 2001).

Concentration of Fe_2O_3 in the soil samples of horizon A and B, collected during the month of January in 2003 and 2004, from the Peshawar piedmont soils, Peshawar floodplain soils and Peshawar lacustrine soils of the Peshawar basin were graphically presentd in Figure 3. The Fe_2O_3 contents of the soils reported by Tariq (2001) from the same sites were also given for comparison of the data. No significant change was found in the iron concentration with the increase and decrease of depth and also with the passage of time. The iron contents were found in the range of 2.85 to 7.98 wt.%, 4.25 to 7.85 wt.% and 3.6 to 5.31 wt.% in Peshawar piedmont, Peshawar floodplain and Peshawar lacustrine soil respectively (Table 1). All these soils had iron contents within the range of normal agricultural soil (i.e., 5.77 wt.%). However, the soils from Peshawar piedmont and Peshawar floodplain had relatively high concentration of iron (Table 1). The iron contents of the Peshawar basin suggest that there is no iron deficiency or iron toxicity in the soils of the basin which can have drastic effect on the ecosystem of the region.

Magnesium oxide (MgO): Magnesium is the least studied ion though it is the second most abundant exchangeable cation in soils. Excessive or deficient amounts are uncommon. Mg

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deficiencies in plants have been reported in some acid sandy soils and are a concern in northern Europe as a by-product of the large amount of acid rain during the past century and continuing (Bohn et al., 2001). The deficiency of Mg in the agricultural soil can be improved by the addition of agricultural dolomite which is containing appreciable amount of Mg impurities (Black, 1968). The MgO concentration in the normal agricultural soil is 0.99 wt.% (Bohn et al., 2001).

The MgO concentrations in the various soils of horizon A and B, collected during the month of January in 2003 and 2004, form the Peshawar piedmont, Peshawar floodplain and Peshawar lacustrine within the Peshawar basin were graphically presented in Figure 4. No significant change was observed in MgO concentration with the depth and also with the passage of time. The MgO varied from 0.59 to 3.58 wt.%, from 1.25 to 3.83 wt.% and from 1.36 to 1.73 wt.% in the soils of Peshawar piedmont, Peshawar floodplain and Peshawar lacustrine respectively (Table 1). The soils of Peshawar piedmont and Peshawar flood plain were found relatively enriched in MgO as compared to that of Peshawar lacustrine. However, the MgO contents of all the soils of the basin were exceeding that of the normal agricultural soil. This soil, therefore, need to be further evaluated as for as the toxicity of magnesium is concerned on the ecosystem of the area.

Calcium oxide (CaO): Most of the crops yield best in soils when Ca^{+2} dominate the exchangeable cations. High Ca indicates a near-neutral pH, which is desirable for most of the plants and soil microorganisms. Calcium is an essential element for plants and animals and the amounts are rarely deficient in soils. However, very high concentration of Ca in the soil are not suitable for the growth of the plants. Though Ca is very important in plant nutrition, but the soils derived from limestone parent material can be unproductive (Adriano, 2001). The CaO concentration in the normal agricultural soil is reported up to 1.44 wt.% by Bohn et al. (2001).

The CaO concentration of the various soil samples of horizon A and B of the Peshawar basin, collected during the month of January in 2003 and 2004 along with the CaO concentration

reported by Tariq (2001) for the soils of the same locations were shown in Figure 5. No significant change of CaO concentration was noticed with depth and also with the passage of time. The CaO ranged from 2.3 to 27.41 wt.% in the soils of Peshawar piedmont; from 4.38 to 13.06 wt.% in the soils of Peshawar flood plain and from 8.12 to 11.99 wt.% in the soils of Peshawar lacustrine (Table 1). Almost all the soils of the Peshawar basin were having high CaO contents as compared to that of the normal agricultural soil; especially the soils of the Peshawar piedmont. This can be attributed to the larger input from the weathering of limestone and dolomite from the surrounding rocks of the basin. The soil of the Peshawar basin should, therefore, be further evaluated in detail for its effect on the ecosystem of the region.

Sodium oxide (Na$_2$O): Sodium in the soil can accumulate to greater extent in the areas inundated by seawater in arid areas where salts naturally accumulate from evaporation of incoming of surface or groundwater and in irrigated soil because irrigation water often contains high Na. Na is not required by plants but can replace part of the K requirement of some plant species. Saline soils are problem for plants because the high osmotic potential of the soil solution makes it unavailable for plants. The plant has to expend so much energy to take up water that little energy is left for growth and crop yield (Bohn et al., 2001). Na is toxic to some plants at high concentrations, but for most plants this is relatively minor problem compared with the restricted water uptake and movement that normally precede Na toxicity (Mortvedt et al., 1972).

The concentration of Na in the normal agricultural soil is 0.99 wt.% as reported by Bohn et al. (2001). The Na concentration in the various types of soil samples, collected during the month of January in 2003 and 2004, from Peshawar piedmont, Peshawar flood plain and Peshawar lacustrine of the Peshawar basin were graphically presented in Figure 6. No significant change was noticed in the concentration of Na with depth and also with the passage of time. The Na contents in the Peshawar piedmont ranged from 0.91 to 2.65 wt.%, from 1.45 to 2.46 wt.% in floodplain and from 1.16 to 2.34 wt.% in the lacustrine soils (Table 1). Almost all the soils of Peshawar

piedmont, Peshawar flood plain and Peshawar lacustrine of the Peshawar basin were having high concentration as compared to that of the normal soil for agriculture. This Na enrichment can be attributed to the water logging and salinity noticed in many parts of the basin. The increasing amount of Na in the soils of Peshawar basin can pose environmental threat to the ecosystem of the region which needs to be further investigated.

Potassium oxide (K_2O): Potassium is the third most important fertilizer element, in terms of amounts added as fertilizer, after nitrogen and phosphorus. Many soils of humid regions are unable to supply sufficient K for agronomic crop. Soils retain K^+ more strongly than Na^+, because the hydrated K ion is smaller than the hydrated Na ion. In addition, K fits well between the sheets of several soil clay minerals, while Na does not, so these minerals contain high concentration of K (Black, 1968). The K concentration in soil solutions is low but is replenished by K diffusion from between the sheets of these clay minerals, from the slower weathering of K-containing feldspar minerals and from decay of soil organic matter. Continued K fertilization is necessary for K-deficient soils. Fixed K is released back to the soil solution too slowly to satisfy plant needs (Bohn et al., 2001; Russell, 2001). The concentration of K_2O in normal agricultural soil is1.2 wt.% (Bohn et al., 2001).

The K concentration in the various types of soils of Peshawar basin, collected during the month of January in 2003 and 2004, have been analyzed and the results along with that of Tariq (2001) from the same localities were shown in Figure 7. It was noticed that K_2O concentration was highly variable and no significant change with increase in the depth and also with the passage of time was noticed. K_2O ranged from 0.58 to 2.62 wt.% in the Peshawar piedmont soil, from 1.32 to 3.12 wt.% in the Peshawar floodplain soil and from 1.70 to 2.45 wt.% in the Peshawar lacustrine soil (Table 1). It was evident from this data that K_2O contents in almost all the samples of the soils from Peshawar basin exceeded that of the normal agricultural soil. This can be attributed to the high amount of K-bearing clay mineral in the soils of the basin. The high concentration of K_2O in the soils of the Peshawar basin can be

unsuitable for agriculture in the region and need to be further evaluated in detail.

3.2.2. *Minor element oxides*

Manganese oxide (MnO): Manganese occurs generally in the accessory minerals in many of the rocks. In the igneous rocks, the Mn is present in the silicates. During weathering the Mn separates out as Mn oxides in the soil (Norrish et al., 1975). In soil, it can occur as dark nodules and coatings. In nature Mn chemically behaves similarly to Fe. In the reducing environment Mn (II) species are most stable, while in oxidizing environments the most stable compound is its oxide (MnO_2). Manganese has several functions in plants. It activates many enzyme reaction involved in the metabolism of organic acid, phosphorus and nitrogen. It is also involved in photosynthesis. Manganese deficiencies have been observed in various crops throughout the world. Its deficiency is common in various crops and causes various types of diseases (Adriano, 2001).

According to Bohn et al. (2001), the MnO contents in the normal soil are generally below 0.1 wt. %. The various soils of horizon A and B from the Peshawar, collected during the month of January in 2003 and 2004, have been analyzed for MnO and the results were shown in Figure 8. MnO contents reported by Tariq (2001) from the same localities of the basin were also given in Figure 8 for comparison. The data suggested no change of MnO concentration with depth and also no significant change in Mn concentration was noticed with the passage of time. The MnO concentrations varied from 0.02 to 0.15 wt.% in the soils of Peshawar piedmont, Peshawar floodplain and the Peshawar lacustrine of the Peshawar basin (Table 1). Majority of the samples contained MnO within the range of normal soil. This suggests that the soils of Peshawar basin are generally safe for agriculture use as far as the Mn concentration is concerned. However, MnO in the soils of Warsak colony, Kafer Dheri, Mathra, Landi Arbab and Phando were exceeding that of normal soil.

Titanium oxide (TiO_2): TiO_2 in the soils is normally contributed from the accessory minerals (such as rutile, sphenes, titanomagnetite etc.) of

all the major rock types. The normal soil has up to 0.88 wt.% TiO_2 (Bohn et al., 2001). No significant change in the concentration of TiO_2 was noted with the increase or decrease of depth and also no significant change in the concentration of TiO_2 with the passage of time was found. TiO2 contents in most of the samples of the Peshawar basin were found within the permissible limit i.e. 0.88 wt.%:(Bohn et al., 2001) but in certain places the TiO_2 contents have exceeded this limit.

Phosphorous pentaoxide (P_2O_5): Phophorous is present in the form of phosphate (PO_4) is the major fertilizer component. Phosphate added to soils is first adsorbed quickly and is later "fixed" into increasingly less soluble status with the passage of time. Phosphate is increasingly unavailable as soil acidity increase, due to retention by Al and Fe. The decay of phosphate in organic matter by passes the inorganic soil fraction to some extent and maintains some phosphate availability to plants over the whole range of soil pH (Russell, 2001). The rate of phosphate loss from soil by weathering is about the same as the overall weathering rate, so that amount of phosphate in soil tends to remain constant throughout soil development. The availability of phosphate to plants, however, decreases as soils become more acidic and the proportion of phosphorous as aluminum and iron phosphate increases (Bohn et al., 2001; Mortvedt et al., 1972). The normal agricultural soil contain about 0.18 wt.% of P_2O_5 (Bohn et al., 2001).

The P_2O_5 concentration in the various types of soils of the Peshawar basin collected during the month of January in 2003 and 2004 along with P_2O_5 contents reported by Tariq (2001) from the same sites were graphically presented in Figure 9. It was evident from the data that the P_2O_5 contents showed significant change with the increase of depth but no significant change in P_2O_5 contents was noticed in these soils with the passage of time. There is generally a decreasing trend of P_2O_5 with depth. The P_2O_5 concentration in the Peshawar piedmont soils varied from 0.25 to 2.56 wt.%, in the Peshawar flood plain soils it varied from 2.12 to 6.90 wt.% and in the Peshawar lacustrine soils it varied from 0.20 to 0.68 wt.%. The Peshawar floodplain soils had relatively high concentration while the Peshawar lacustrine soils have relatively low concentration of P_2O_5.

However, almost all the samples of soils of the Peshawar basin have high concentrations of P_2O_5. This increase of P_2O_5 in the studied soils can be attributed to the use of fertilizers and also to the weathering of alkaline rocks present in the northwestern and northeastern part of the basin. The concentration of P_2O_5 in the soils of the basin can cause drastic negative effects on the ecosystem of the region and need to be further evaluated.

4. Conclusions

The soils of Peshawar basin were analyzed for determination of major element oxide indicated useful information for normal agricultural activities of different types of soils in the Peshawar basin. Majority of the major element oxides were within permissible limit having no variation in the composition of soil with passage of time from 2002 to 2004. In general, the soil samples were enriched with high concentration of Al_2O_3. The soils of Peshawar piedmont and Peshawar floodplain, however, have relatively high concentration of Fe_2O_3. The concentration of MnO in majority of the soil samples were found within the range but exceeded the limits at few places. The soils of Peshawar piedmont and Peshawar flood plain had higher contents of MgO as compared to Peshawar lacustrine soils. All the soil samples of the Peshawar basin had high loads of CaO, K_2O and P_2O_5 compared to the standards fixed for normal agricultural soil. This study suggests that overall, no significant change in the concentration of the major and minor element oxides has been noticed with change in depth and also with the passage of time.

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